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World's most civil servant

World's worst title

Martha: a next generation testable language

Not a "language" but AI agents to help analysts explore a range of model behaviors

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A change of view

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- **As is**
  - Requirements, analysis, design
    - Explore options
  - Code
    - Enshrine the decisions
- **To be**
  - Don't "code" but "codes"
    - Scribble down the options
    - Run them, see how they behave
  - Deliver the system
    - AND the operations manual
    - AND the work-arounds
  - E.g. ISS issue logs: "n" denotes known issues with work-arounds:
    <1, 1n, 2, 2n, 3, 4, 5>
- **But how to encode the options?**

The “best language” myth

Lesson: there is no one best language
Case study: from LURCH to SPY
Best we can hope for is to cover range of possible languages

Case studies

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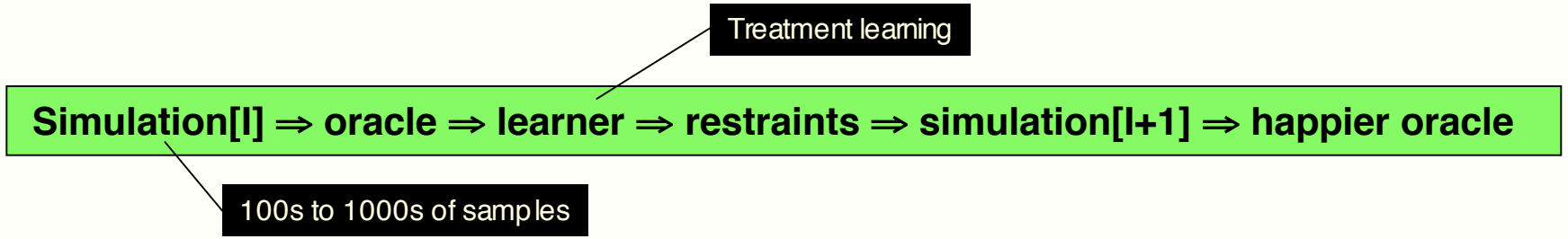
- **NEAR: "language" = influence tables**
- **SILAP: "language" = functional network**
- **DDP: "language" = semantic net**
- **In all cases:**
  - Languages have sentences
  - Languages execute
  - Execution scored by oracles
  - Sentences have choice points
  - Choice points selected from distributions
  - Data mining find distributions restraints that make the oracles happier



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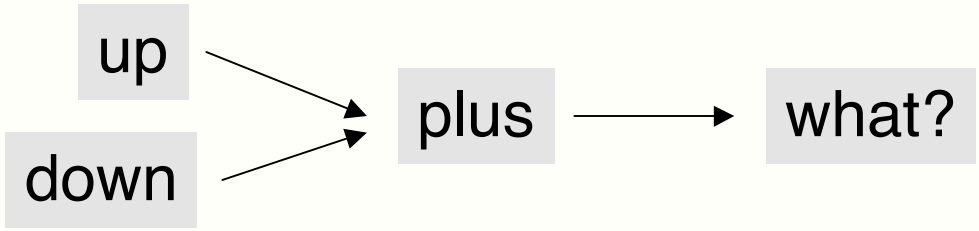
Case study 1

NEAR: “language”= influence tables

(work with Dr. Julian Richardson, RIACS)



Tables of qualitative influences

id	software process option	safety	dev. time	dev. cost	life cycle cost	capability
1	target critical mission phases	+	+	+	-	-
2	target critical commands	+	+	+	-	-
3	target critical events	+	+	+	-	-
4	onboard checking	+	-	-	+	0
5	reduce flight complexity	+	+	+	?	-
6	test fly prototypes	+	+	+	?	?
7	enhance safing	+	-	-	+	?
8	certification	+	?	?	?	?
9	increase vv	+	-	-	+	?
10	reduce onboard autonomy	?	+	+	-	-
11	reuse across missions	?	+	+	?	?
12	increase developer capabilities	+	+	+	?	?
13	increase developer tool use	+	+	+	?	?
14	implement optional functions after launch	?	+	?	?	?
15	reduce vv cost	0	0	+	+	0
16	increase vv speed	0	+	0	0	0
17	increase vv capabilities	+	+	+	0	+

Nondeterminant: "-" and "+" = what?

Monte Carlo to sample model structure

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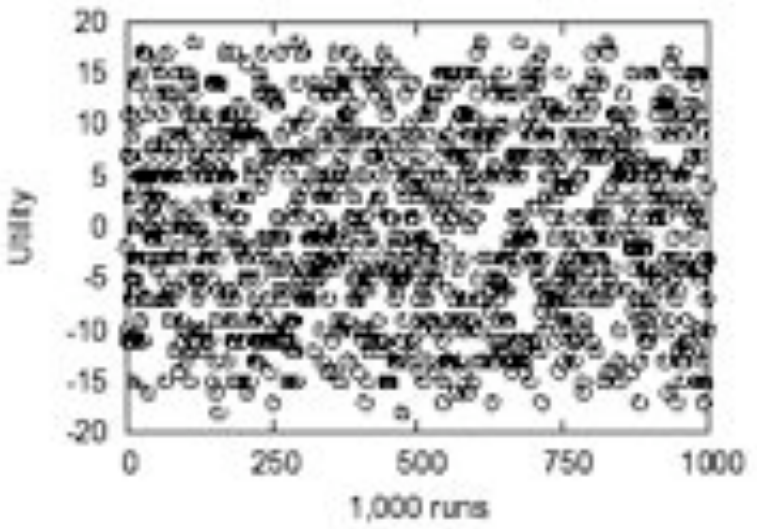
- **Utility = sum(Goal(X) * Impact(Option,X))**
- **Goals:**
  - 0 <= Safety <= 10
  - 0 <= DevTime <= 10
  - 0 <= DevCost <= 10
  - 0 <= LifeCycleCost <=10
  - 0 <= Capacity <= 10
- **Er… what structure?**

id	software process option	safety	dev. time	dev. cost	life cycle cost	capability
1	target critical mission phases	+	+	+	-	-
2	target critical commands	+	+	+	-	-
3	target critical events	+	+	+	-	-
4	onboard checking	+	-	-	+	0
5	reduce flight complexity	+	+	+	?	-
6	test fly prototypes	+	+	+	?	?
7	enhance safing	+	-	-	+	?
8	certification	+	?	?	?	?
9	increase vv	+	-	-	+	?
10	reduce onboard autonomy	?	+	+	-	-
11	reuse across missions	?	+	+	?	?
12	increase developer capabilities	+	+	+	?	?
13	increase developer tool use	+	+	+	?	?
14	implement optional functions after launch	?	+	?	?	?
15	reduce vv cost	0	0	+	+	0
16	increase vv speed	0	+	0	0	0
17	increase vv capabilities	+	+	+	0	+

Nondeterminant: "-" and "+" = what?



Seek the “lift” structure

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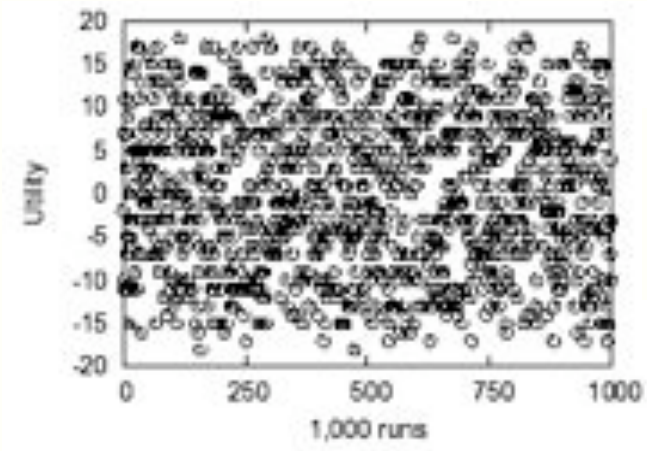
- **Divide scores into low, medium, high (scored 2,4,8)**
- **Baseline= (2 * # lows) + (4 * # mediums) + (8 * # highs)**
- **lift(attribute=range) = log((all ∩ range)/baseline)**
  - Lift = 0 if useless
  - Lift > 0 if useful
  - Lift < 0 if dangerous
- **Often, a few outstanding ranges**



=>

lift1	frequency
-3:	[1]
-1:	[1]
0:	[59]
1:	[20]
2:	[5]
3:	[6]
4:	[1]

Build “super lifters”

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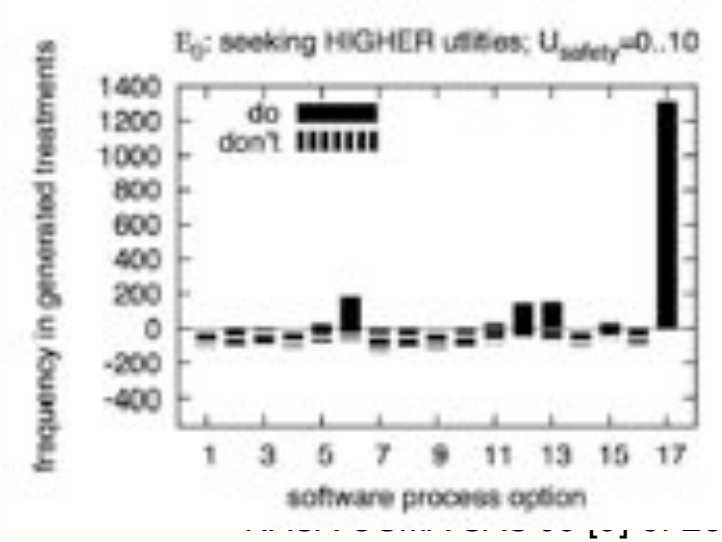
- **“Super lifter” = combinations of ranges with high lift**
- **Found = ()**
- **Interesting = 5**
- **While Interesting**
  - 100 times do
    - Build treatments using ranges with higher lifts (selected randomly)
  - Best = top 20
  - if Best in Found then
    - Interesting --
  - Else
    - Interesting = 5
    - Found = Found + Best



Apparent noise + treatments = improvement

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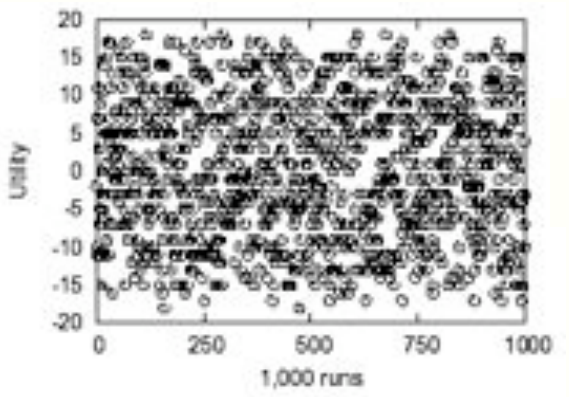
Mean utility doubles (20 to 35.9)



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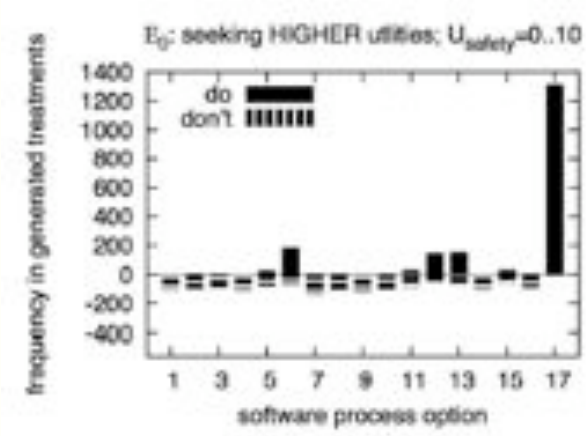

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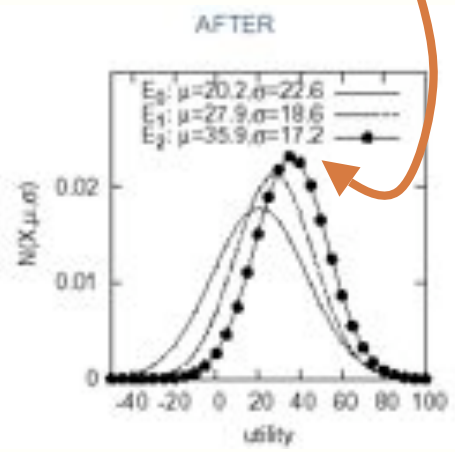
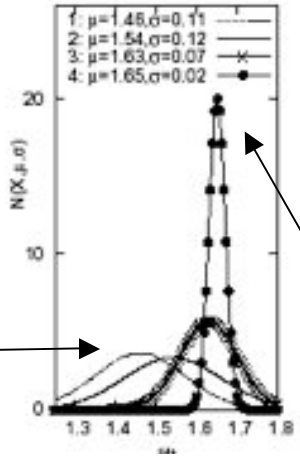


Q: But what about the variance?
A: larger and larger treatments
= less and less variance



1 lifters

4 lifters

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Case study 2

SILAP: “language”= functional network

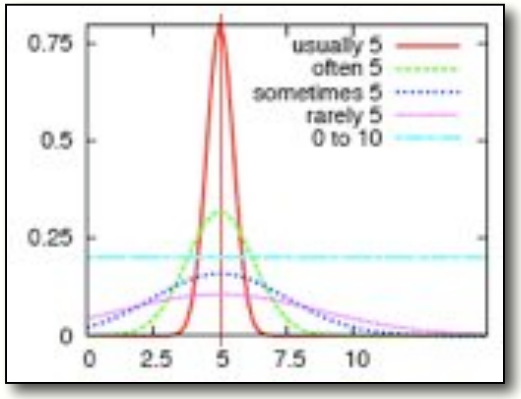
(work with Marcus Fischer, IV&V)

```
All["Experience"                ] = 0.8 to 0.9   ;
All["SoftwareDevelopment"       ] = 0.4 to 0.7;
All["Complexity"                ] = often  0.547 ;
All["Innovation"                ] = often  0.351 ;
All["SoftwareProcess"           ] = 0.1 to 0.4 ;
All["Maturity"                  ] = often  0.242 ;
All["Reuse"                     ] = often  0.226 ;
All["Organization"              ] = often  0.172 ;
All["SoftwareCharacteristics"] = often  0.172 ;
All["FormalReviews"             ] = often  0.1119;
All["SoftwareSize"              ] = often  0.102 ;
All["ConfigManagement"          ] = often  0.0962;
All["Standards"                 ] = often  0.0955;
All["DefectTracking"            ] = often  0.0873;
All["CMM"                       ] = often  0.0764;
All["RiskManagement"            ] = often  0.0647;
```

```
One["Experience"        ] = 4;
One["Organization"      ] = 2 to 4;
One["Complexity"        ] = usually 2;
One["Innovation"        ] = usually 4;
One["SoftwareSize"      ] = usually 2;
One["Standards"         ] = often 2;
One["ConfigManagement"] = sometimes 5;
One["CMM"               ] = sometimes 1;
One["FormalReviews"     ] = rarely 3;
One["DefectTracking"    ] = rarely 3;
One["RiskManagement"    ] = rarely 3;
One["Reuse"             ] = rarely 3;
One["Maturity"          ] = rarely 3;
```

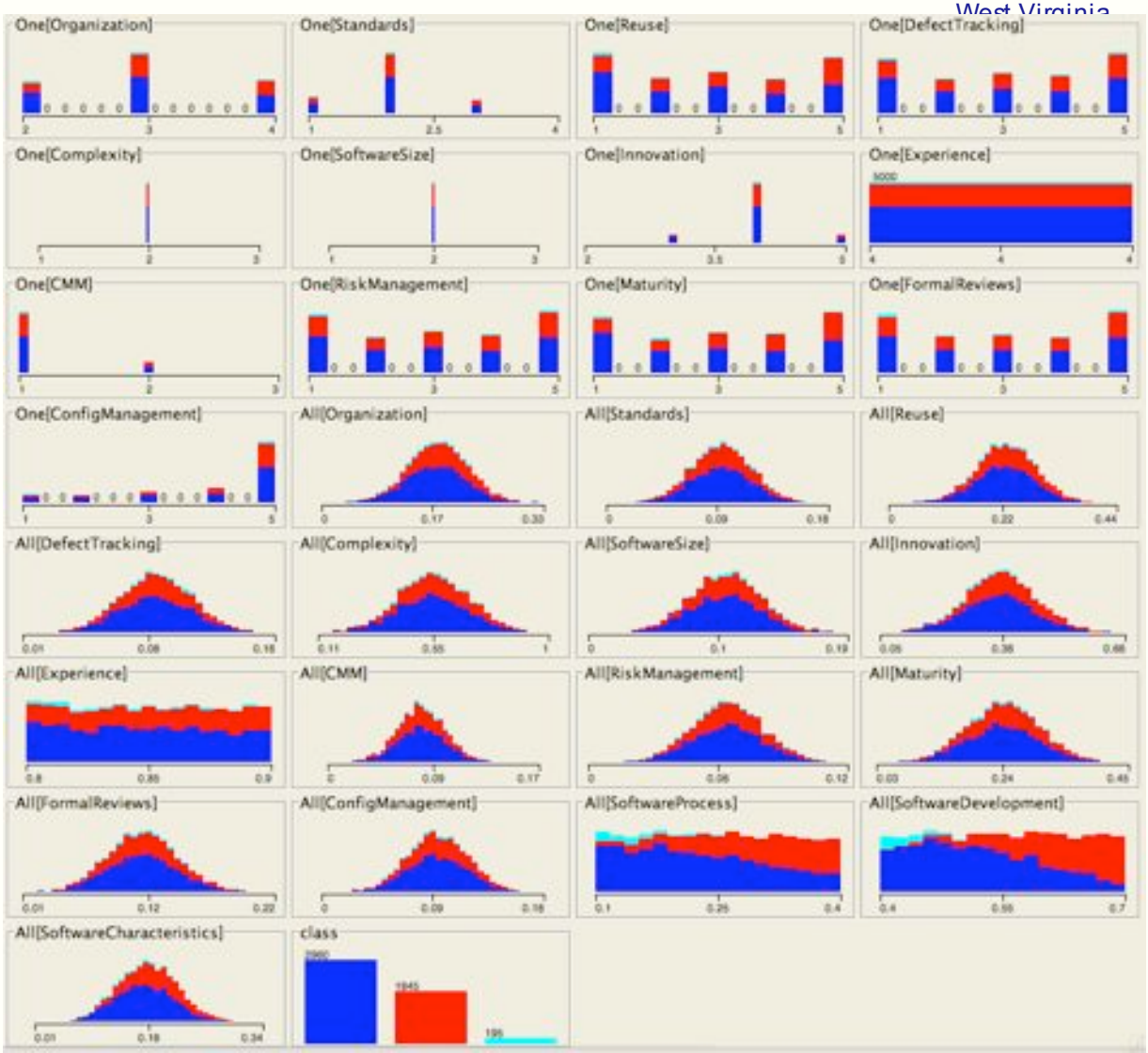
Warning: made up numbers!

```
BEGIN {
  to          = " to ";
  usually     = "0.1x";
  often       = "0.25x";
  sometimes   = "0.5x";
  rarely      = "0.75x";
}
```




```
function the(y) { return one(y) * all(y) }

function development() {
  return the("Experience") + the("Organization");}

function software()     {
  return the("Complexity")+the("Innovation")+ the("SoftwareSize")}

function process() {
  return the("Reuse") + the("Maturity") +
         the("CMM") + the("FormalReviews") +
         the("Standards") + the("ConfigManagement") +
         the("DefectTracking") + the("RiskManagement") +

function errorPotential() {
  return (all("SoftwareProcess") * process()) +
         (all("SoftwareDevelopment")* development()) +
         (all("SoftwareCharacteristics")* software())}
```

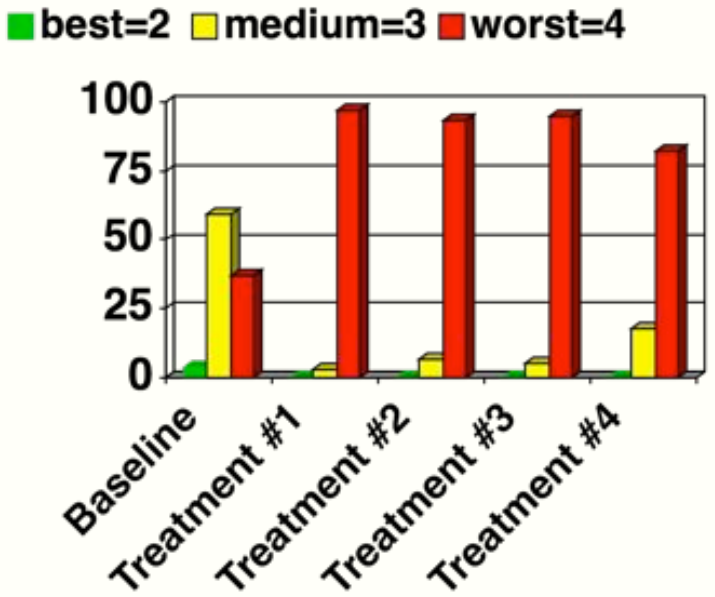
After 5000 runs

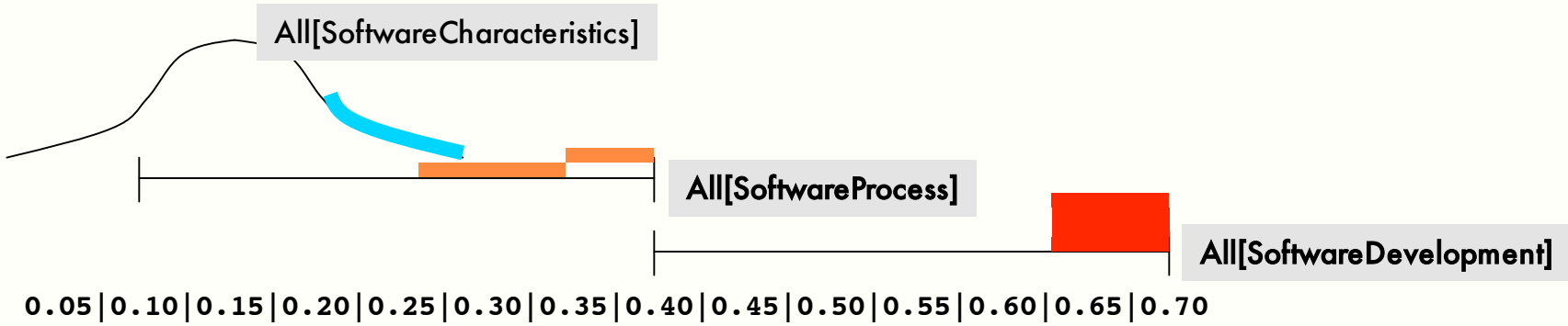


- **Lottsa data.**
- **What does it all mean?**
- **Q: What are the key patterns?**
- **A: Use the lift heuristic**

Treatment Learning results

- **Treatment #1 (top):**
  - All[SoftwareProcess] = 0.34 to 0.4
    and All[SoftwareDevelopment]= 0.64 to 0.7
- **Treatment #2:**
  - All[SoftwareCharacteristics]=0.21 to 0.34
    and All[SoftwareDevelopment]=0.64 to 0.7
- **Treatment #3:**
  - All[SoftwareDevelopment]= 0.64 to 0.7
    and All[SoftwareProcess]= 0.28 to ..0.34
- **Treatment #4:**
  - One[RiskManagement]=5
    and All[SoftwareDevelopment]=0.64 to 0.7





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Case study 3

DDP: Cornford & Feather's requirements engineering language

(work with James Kiper, Jeremy Greenwald)

DDP

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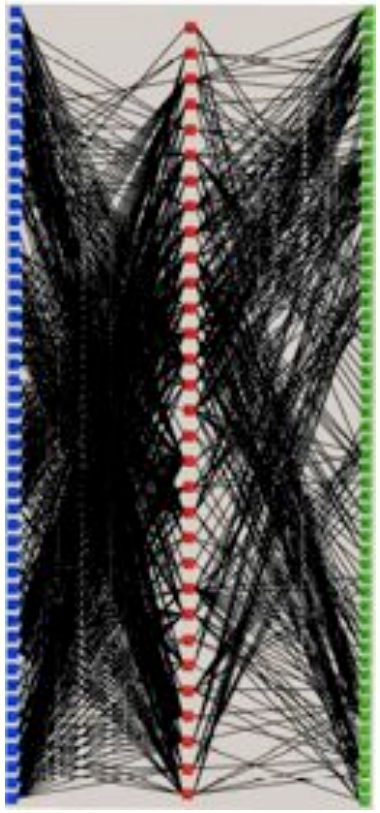


analyze this

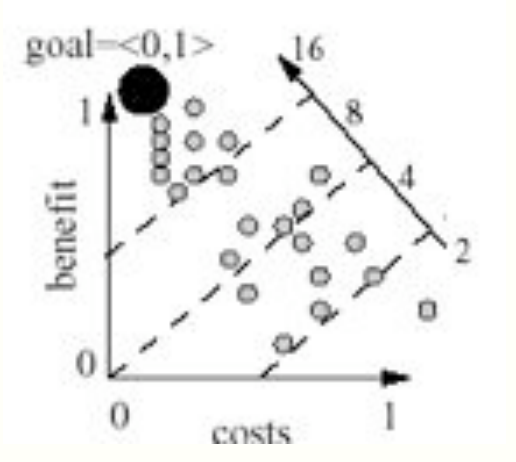
- **Cornford and Feather**
  - Visual tool for “group think”
  - RISKS hurt REQUIREMENTS
  - MITIGATIONS remove risks, cost money.
  - Seek cheap mitigations resolving risks that hurt the important requirements
- **Has been used for:**
  - Starlight, Deep Space 1&2, X2000 electronics packages; Interferometry design; Mars Globa Surveyor extended missions, Technology Infusion/Maturity assessments, ...
- **Being used for:**
  - SCrover: University of Southern California’s autonomous rover
  - Will be used for
  - Cost and risk models for autonomous systems

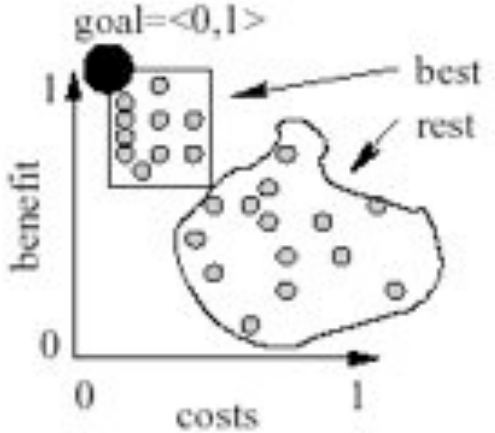
Optimizing DDP: learn better mitigations via via random mitigation selection

- **Use AI to find the cheapest mitigations that result in the greatest number of covered requirements**
  - Score1 = (benefit1 + cost1)/2
  - Benefit1 = benefit / maxBenefit
  - Cost1 = 1 - (cost /maxCost)
- **Methods:**
  - Simulated annealing (optimization method for non-linear systems)
    - Standard : use Score1
    - Regularized: Score1/(# actions +1)
  - Treatment learning with
    - D: diagonal classification
    - Bore: best or rest sampling
    - Surfer: a treatment learner decision support tool

- **Diagonal classification: N classes**

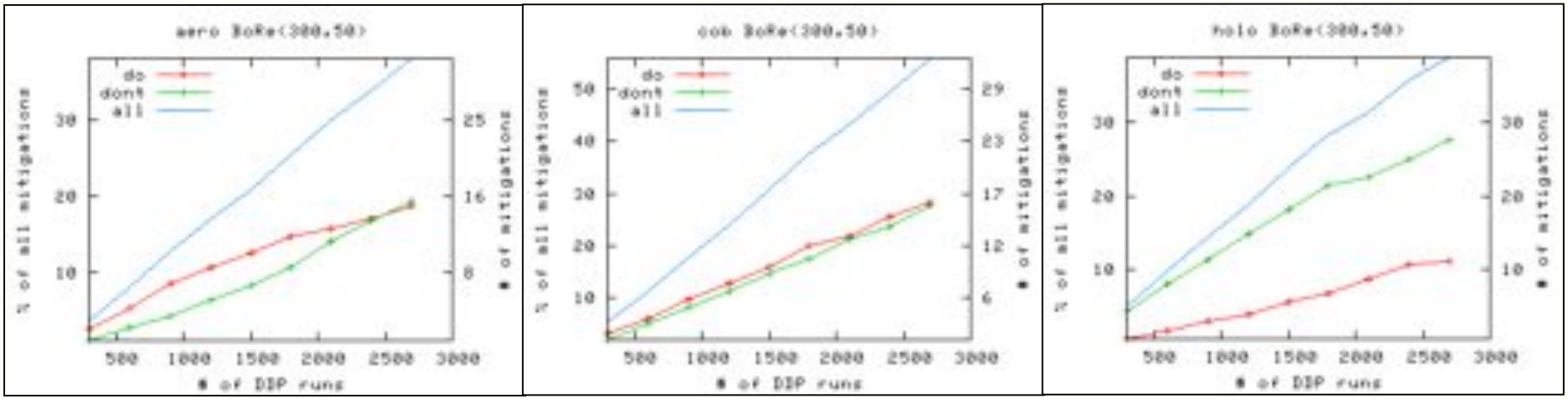
- **Bore: 2 classes**





Surfer

Currently, under the hood, SURFER calls treatment learning.
This may change…..



no more brittle point solutions

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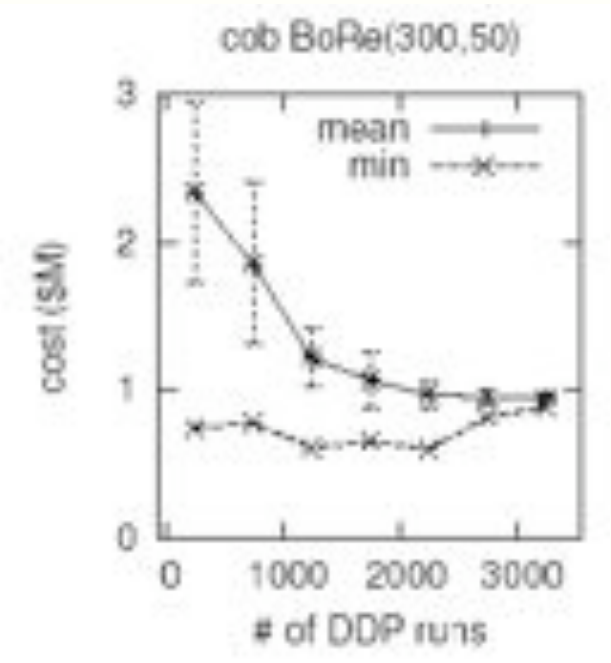

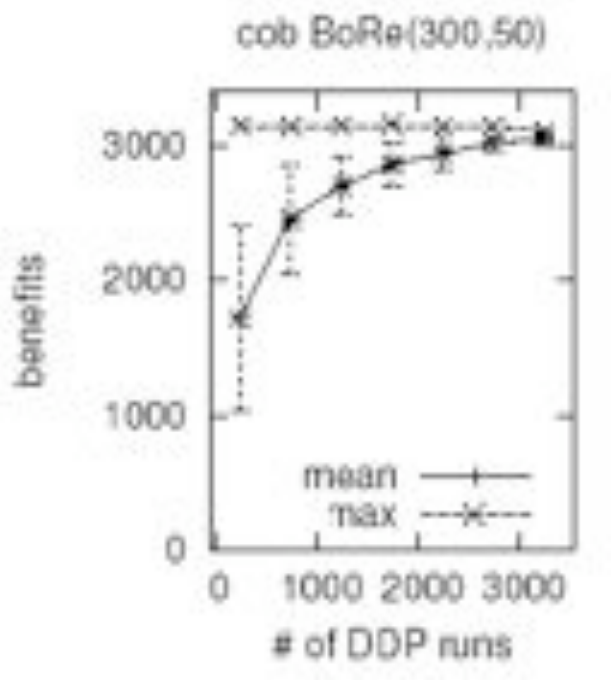

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Enough with the case studies

Technology Readiness Level of the Work = 5

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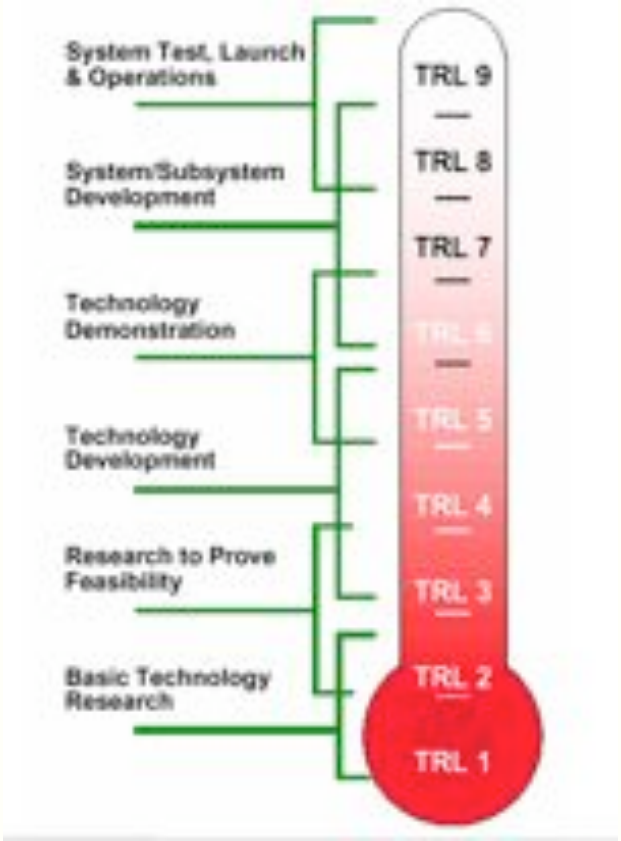

- **5:**
  - Component and/or breadboard validation in a relevant environment

Potential Applications

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- **Software process modeling when process details unclear**
- **Assemblies of systems from different developers**
- **Teams exploring options prior to large builds**
- **Decision making under uncertainty**
- **Simulation-based acquisition**
- **Solo developers**

Availability of data or case studies

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DDP: see Martin Feather at JPL

SILAP: see Marcus Fischer at IVV

NEAR: http://menzies.us/pdf/05qrre.pdf

Barriers to research or applications

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- Getting more examples
- Exploring option space is impossible without the options

Next Steps

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- **More case studies**
  - SILAP: lots to do
  - Team X: excellent test bed
  - Synergy with HRT project on cost-benefits autonomous systems
- **Generalization**
  - N case studies
  - Reusable “marthas” extracted from the case studies
- **Better restraining policies**
  - Use internals of data miner to define what to try next
    - Bayesian analysis